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# Influence of Chloride on Growth, Fruit Yield and Quality Parameters of Processing Pepper

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## ABSTRACT
This study was carried out to investigate the effects of irrigation water containing different $Cl^-$ on plant growth parameters, fruit yield and quality characteristics of pepper (*C. annuum* L. cv. Postal Capija). Nutrient solutions containing $Cl^-$ concentrations were applied to processing pepper plants and effects of $Cl^-$ on growth parameters, fruit yield and quality traits, leaf water potential and chloride contents were determined. Greenhouse experiments were conducted with the $Cl^-$ concentrations [control (0.27), 1.5, 3.0, 4.5, 6.0, 7.5 and 15.0 mM] were applied to pepper plants. Plant height, fresh and dry weight, fruit yield and fruit weight, length and diameter were not affected by increasing $Cl^-$ concentrations up to 3.0 mM, but further increases in $Cl^-$ concentration negatively influenced this results. The greatest dry matter and soluble solids content were obtained from 3.0 and 4.5 mM $Cl^-$ treatments. Increasing $Cl^-$ concentration increased fruit acid content; the greatest acid content was from the greatest $Cl^-$ concentration. Increasing growing media $Cl^-$ concentration increased leaf $Cl^-$ accumulation and $Cl^-$ concentration >3.0 mM reduced leaf water potential. Research results showed that $Cl^-$ concentrations in irrigation water are important for efficient and economical pepper cultivation, and using water containing more than 3.0 mM chlorine will jeopardize yield and quality.

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# Klor Uygulamalarının Biber Bitkisinin Gelişimi, Meyve Verimi ve Bazı Kalite Parametreleri Üzerine Etkisi

## ÖZET
Bu çalışmada, salçalık biber (*C. annuum* L. cv. Postal Capija) bitkilerine farklı $Cl^-$ içeren besin solüsyonları uygulanmış ve biberin büyüme parametreleri, meyve verim ve kalite özellikleri, yaprak su potansiyeli ve klor içerikleri araştırılmıştır. Sera şartlarında yapılan araştırma tesadüf parselleri deneme desenine uygun ve dört tekerrürlü olarak planlanmış, bitkilere yedi farklı $Cl^-$ [kontrol (0.27), 1.5, 3.0, 4.5, 6.0, 7.5 and 15.0 mM] uygulaması yapılmıştır. Sonuçlar, $Cl^-$ konsantrasyonunun 3.0 mM'e kadar yükselmesinden; büyüme parametreleri (bitki boyu, bitki yaş ve kuru ağırlığı) meyve verimi ve meyve karakteristiklerinin (meyve ağırlığı, meyve çap ve boyu) etkilenmediğini, ancak bu seviyenin üzerinde artan $Cl^-$ konsantrasyonlarının söz konusu değerleri olumsuz etkilediğini göstermiştir. En yüksek meyve kuru madde ve suda çözünür kuru madde içerikleri 3.0 and 4.5 mM $Cl^-$ uygulamalarında tespit edilmiştir. Buna karşın, $Cl^-$ konsantrasyonlarındaki artış meyve asit içeriklerini de arttırmış ve en yüksek asit içeriği yüksek $Cl^-$ uygulamasında bulunmuştur. Yetiştirme ortamında artan $Cl^-$, yapraklarda daha fazla $Cl^-$ birikmesine neden olmuş, (>3.0 mM) yaprak su potansiyelini ise düşürmüştür. Bu araştırmadan elde edilen sonuçlar, besin solüsyonu $Cl^-$ kapsamındaki artışların bitki büyümesi, verim ve meyve özelliklerinde önemli azalmalara neden olabileceğini, biberlerin sulanmasında kullanılan solüsyonun $Cl^-$ kapsamlarının da dikkate alınmasının ne kadar gerekli olduğunu göstermiştir.

**Araştırma Makalesi**

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**Anahtar Kelimeler**
*Capsicum annuum,*
Klorlu su,
Suda çözünür kuru madde,
Toplam asitlik

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## INTRODUCTION

Chloride plays a role in photosynthesis and water balance in plants and is an essential micro-nutrient for plant growth and development (Chen et al., 2010). Vegetables crops generally have a low $Cl^-$ requirement and low levels are up taken from the soil. Chloride may have toxic effects at relatively low concentrations and may result in irreversible damages in plants (Welch, 1995).

Water with different $Cl^-$ concentrations is commonly used in irrigation of plants (Narkis et al., 1995; Rav Acha et al., 1995). Chloride ions are the most common toxic element encountered in irrigation water. Chlorine is not adsorbed by soil colloids, moves easily with soil water, and easily up taken by roots and transferred to leaves (Ayers and Westcot, 1985; Al Obaidy et al., 2014).

Chloride may intrude into ground waters from decomposition, seepage through sedimentary rocks, saline water intrusion into soils, wind-drifted salts, domestic and industrial wastewater discharges, and municipal wastewaters (Karanth, 1987; Hadian et al., 2015). Plants could be exposed to greater quantities of chlorine because of increasing use of chlorinated domestic and industrial wastewaters in agriculture. Treated wastewater effluents can be used in irrigation (Narkis and Kott, 1991; Rav Acha et al., 1995). Irrigation water is among the primary $Cl^-$ sources in soils (Karaivazoglou et al., 2005). Irrigation water $Cl^-$ concentrations of <70 mg $L^{-1}$ improves plant yield (As et al., 2007; Smith et al., 2016). Ground water with $Cl^-$ contents up to 70 mg·$L^{-1}$ is suitable for irrigation and does not pose serious threats to production. Chloride concentration over 350 mg·$L^{-1}$ may result in toxic effects. Chloride ion concentrations in ground waters, used in irrigation, are between 0.70-153.55 me·$L^{-1}$ and allowable limit for irrigation waters is 11.54 me·$L^{-1}$ (Adhikary et al., 2014).

The red pepper (*Capsicum annum* L.), 'Postal Capija', is used in pepper paste production, roasted and oiled pepper production (Hekimoglu and Altındeger, 2019). This study was conducted to investigate effects of $Cl^-$ concentration in irrigation water on plant growth, fruit yield and quality of pepper.

## MATERIAL and METHODS

The experiments were conducted in a plastic-covered greenhouse of the Mustafakemalpasa Vocational School of Uludag University in Bursa, Turkey (latitude of 40°01′ N, at longitude 28°22′ E with an altitude of 22 m above sea level), from May-August 2020. 'Postal Capija' pepper seedlings were supplied from a commercial producer (Marmara Seedling Product. Agri. Industry Trade Ltd. Co., Bursa, Turkey). The experiment was arranged in a completely randomized design with 4 replications. Three plastic pots (height 40 cm, diameter 30 cm) were used in each replicate and a single plant was maintained in each pot. Pots were filled with 25 kg of air-dried sand-clay-loam soil (60% sand, 21% clay, 19% silt, 1.3% organic matter, 10.3% lime, 35.6 mg $L^{-1}$ phosphorus, 355.20 mg $L^{-1}$ potassium, 0.09% total nitrogen, pH = 7.4, EC= 0.49 dS·$m^{-1}$, field capacity FC= 25%, permanent wilting point PWP = 13% and bulk density 1.23 g·$cm^{-3}$). Soils were passed through a 4 mm sieve before being placed in pots. Holes, over laid with a 5 cm sand-gravel mix, were provided to facilitate drainage of excess water. Pepper seedlings were planted in pots on 20 May. Throughout the growing season, average temperature under the high tunnel was 26.4°C and average relative humidity 66.2%. Cultural processes described by Salk et al. (2008) were practiced, herbicides were not applied and weeds were controlled manually.

Nutrient solution (Hoagland and Arnon, 1950) was used in irrigations during the initial 10 days, and then experimental treatments were applied. In the control, nutrient solution with 9.5 mg·$L^{-1}$ (0.27 mM) $Cl^-$ content was applied and additional chloride was not applied. In chlorine treatments, the $Cl^-$ levels were: 1.5 mM (53.18 mg·$L^{-1}$), 3.0 mM (106.35 mg·$L^{-1}$), 4.5 mM (159.53 mg·$L^{-1}$), 6.0 mM (212.70 mg·$L^{-1}$), 7.5 mM (265.88 mg·$L^{-1}$), and 15.0 mM (531.75 mg·$L^{-1}$). Chloride concentrations were prepared with sodium hypochlorite (NaOCl). In all treatments, $Cl^-$ was added to nutrient solution, mixed, and applied to soil in pots as a drench. Pots were covered with polyethylene to reduce evaporative losses. Irrigation was initiated based on evaporation from Class-A pan and pan coefficient was 1.0 (Kırnak et al., 2002). Irrigations were generally twice a week.

Plant height was measured just before harvest from the root collar to the apical growing tip. In control, and $Cl^-$ treatments, plants were removed at the end of the experiment. Plants were cleaned with water and separated into roots, stems and leaf sections. All sections were weighed to determine fresh weights. Samples were placed in a forced air oven at 80°C for 48 h and reweighed to determine plant dry weights.

Fruit harvested from each treatment were weighed and average fruit weight determined. Ten fruit were randomly selected from each treatment and fruit diameter and length. To determine fruit yield per plant fully-ripened (full-red color) fruit were harvested on 14, 25 and 31 August and weighed, and summed to determine total yield.

For leaf $Cl^-$ content, water-extracted dry leaf samples were stained with potassium chromate indicator and titrated with $AgNO_3$ (Chapman and Pratt, 1961). Leaf water potential was determined following Sairam et al. (2002). Mature leaf samples collected between 14.00-14.30 were used. Four disc samples (1.5 cm dia) were removed from leaves, fresh weight of leaf discs were determined, samples were placed into 100 mL distilled water for 4 h and turgor weight determined. Leaf samples were placed in a forced air oven at 65°C for 48 h and reweighed to determine leaf relative water contents.

Eight fruit were randomly sampled from each replicate of each treatment. Samples were washed with tap water, and rinsed in distilled water. Seed were removed and samples ground. Resultant fruit pulp was placed in a forced air oven at 80°C for 48 h to obtain fruit dry matter content. Soluble solids content (SSC) of fruit juice was measured with a refractometer (Abbe-type refractometer, model 60/DR, Bellingham & Stanley Ltd., Kent, UK). Total acidity was determined through titration with 0.1 N NaOH (Anonymous, 1968).

Data were subjected to analysis of variance in SPSS (SPSS® Statistics for Windows, ver. 20.0, IBM Corp., Armonk, NY). Means were separated with use Duncan's multiple range test. Regression analysis was performed on the relationships between $Cl^-$ concentrations and growth parameters, yield and fruit characteristics in pepper.

## RESULTS and DISCUSSION

Increasing $Cl^-$ concentrations affected growth of plants. There was a good negative linear relationship between plant height, plant fresh weights, plant dry weights and $Cl^-$ concentration (Figure 1).

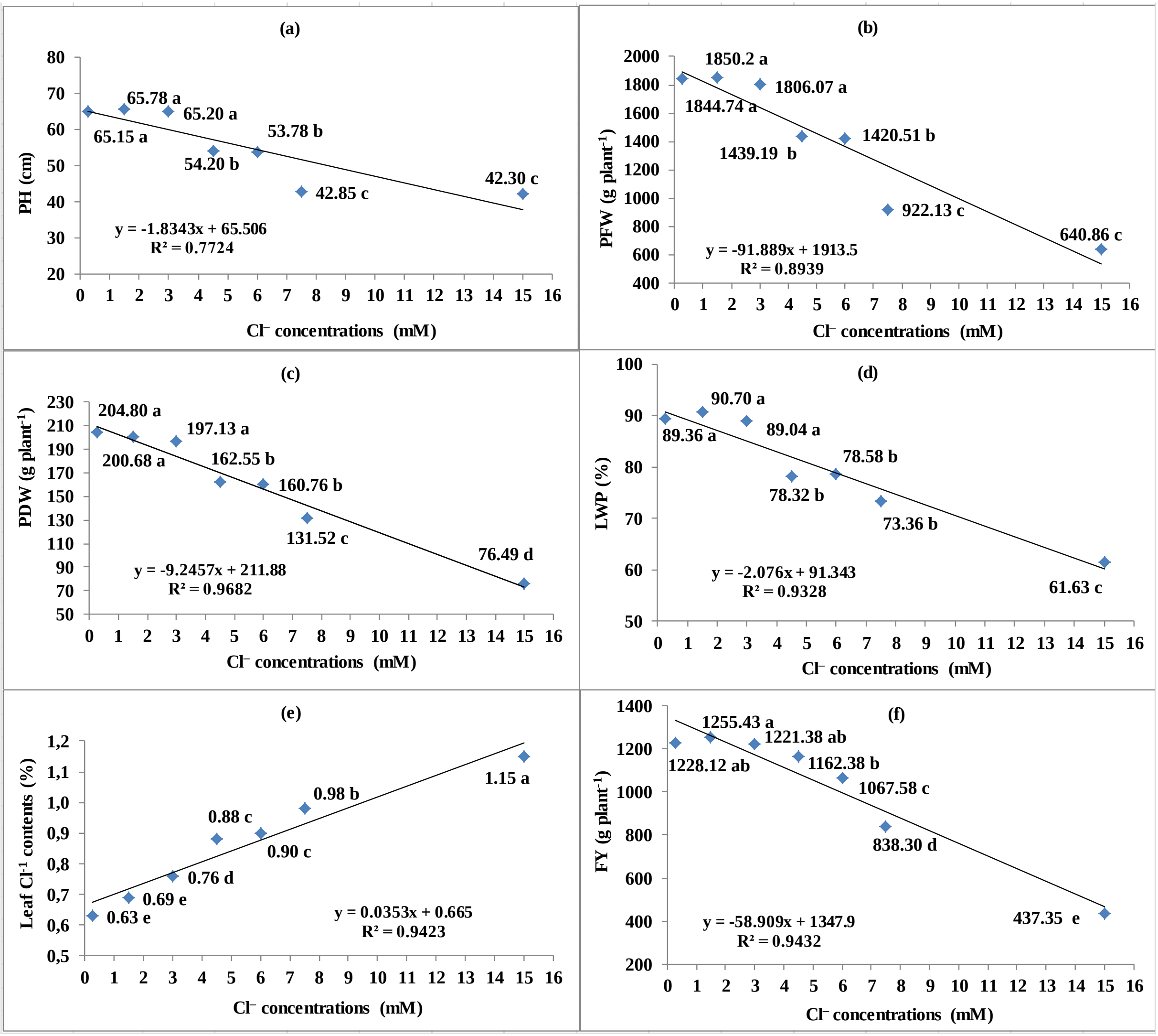


Figure 1. Effect of irrigation water chloride concentrations on pepper plant growth, leaf water potential and chloride content, yield.

*Şekil 1. Sulama suyu klor konsantrasyonlarının biber bitkisinin büyümesi, yaprak su potansiyeli ve klorür içeriği, verim üzerine etkisi*

As:, *PH* plant height (a), *PFW* plant fresh weight (b), *PDW* plant dry weight (c), *LWP* leaf water potential (d), *$Cl^-$* chloride (e), FY fruit yield (f)

Plant height, plant fresh and dry weights were not influenced by $Cl^-$ concentrations up to 3.0 mM level, but further increases in $Cl^-$ concentration reduced responses. Plant fresh and dry weights were higher at 3.0 mM $Cl^-$ than at 15.0 mM $Cl^-$. Chlorine can have an inhibitor role on plant growth (Navarro et al., 2000; Scholberg et al., 2000).

The growing media $Cl^-$ concentrations was well correlated with leaf relative water contents, (Figure 1). Decreasing leaf water contents occurred with increasing $Cl^-$ concentrations. Concentrations of $Cl^-$ up to 3.0 mM did not affect leaf water potential, but further increases in $Cl^-$ concentrations reduced leaf water potentials which agrees with Turhan and Kuscu (2019) indicating reduced leaf water potentials negatively affect conditions within the root zone.

Leaf $Cl^-$ content was positively influenced by increasing $Cl^-$ level. Increasing leaf $Cl^-$ contents occurred with increasing irrigation water $Cl^-$ concentrations (Figure 1) which agrees with Komosa and Gorniak (2015) and Kowalczyk et al. (2008). The greatest leaf $Cl^-$ content was from the 15.0 mM treatment. Decreasing nutrient solution $Cl^-$ concentration reduced leaf $Cl^-$ contents and the lowest leaf $Cl^-$ contents were observed in the control and 1.5 mM $Cl^-$ treatments. Increasing growing media $Cl^-$ concentrations increased plant $Cl^-$ uptake and reduced uptake of the other nutrients through antagonistic effects (Shawer, 2014).

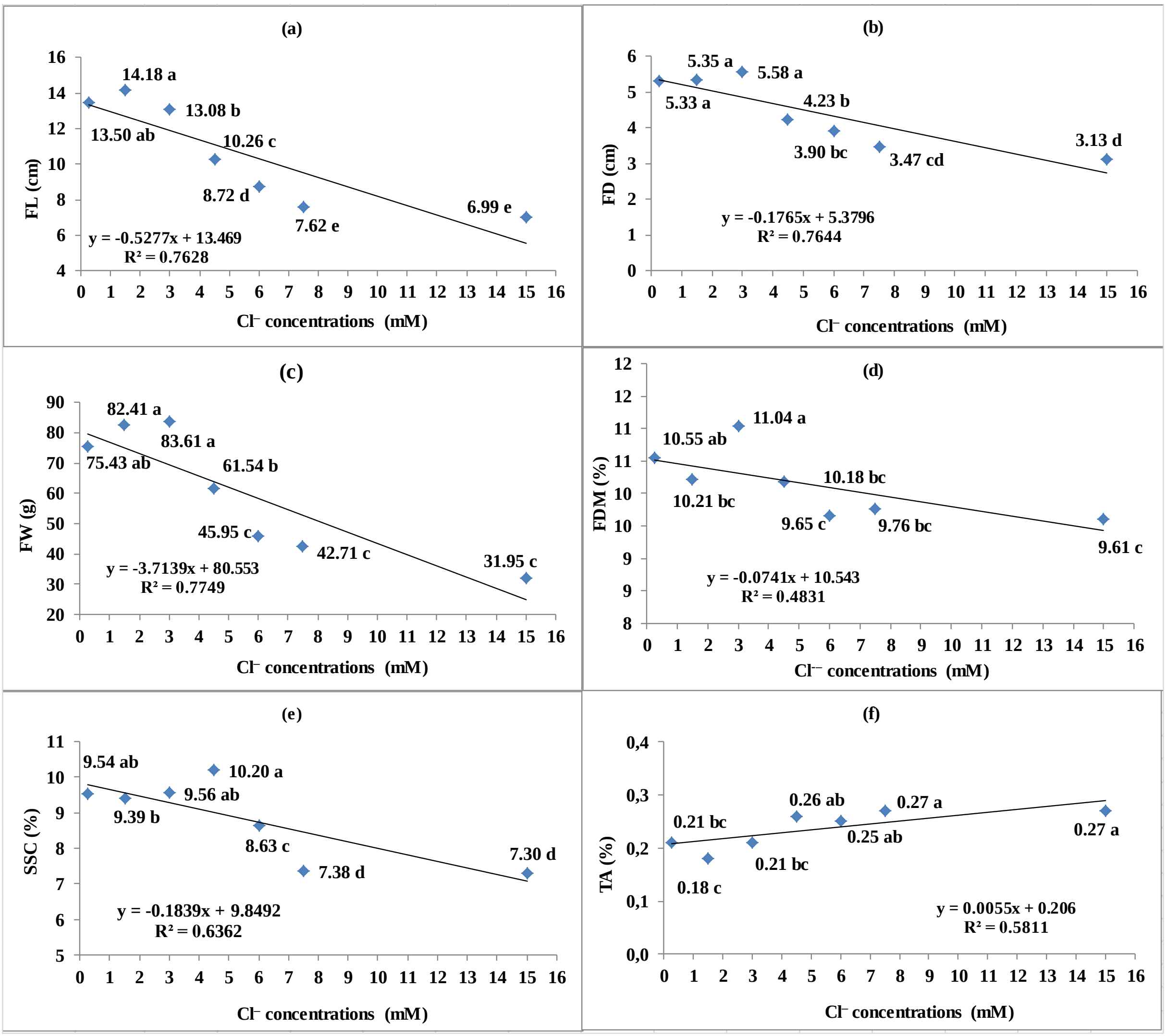


Figure 2. Effect of irrigation water chloride concentrations on fruit characteristics of pepper plant.
Şekil 2. Sulama suyu klor konsantrasyonlarının biber bitkisinin meyve özellikleri üzerine etkisi
As: *FL* fruit length (a), *FD* fruit diameter (b), *FW* fruit weight (c), *FDM* fruit dry matter (d), *SSC* fruit soluble solids contents (e), *TA* fruit total acidity (f)

There were significant, negative, linear relationship between pepper yield and $Cl^-$ concentrations (Figure 1). The $Cl^-$ concentrations up to 3.0 mM resulted in slight changes in fruit yields and the greatest fruit yield was obtained from 1.5 mM $Cl^-$ treatment. The $Cl^-$

concentration of 4.5 mM, and greater, reduced fruit yields. The lowest fruit yield was from 15.0 mM $Cl^-$ treatment. It was reported that low $Cl^-$ levels increased total and marketable yields in tomato, but high $Cl^-$ concentrations negatively influenced yield (Komosa and Gorniak, 2015). Yield reductions mostly come from smaller fruit (Tantawy, 2007).

A negative linear relationship occurred between $Cl^-$ treatments and fruit length and diameter (Figure 2). Variance analysis indicated $Cl^-$ treatments affected fruit physical characteristics. The heaviest and widest fruit were from 3.0 mM $Cl^-$ treatment and the longest fruit were from 1.5 mM $Cl^-$ treatment; increasing $Cl^-$ concentration negatively influenced fruit characteristics. High $Cl^-$ concentration (15.0 mM) had highly significant, negative, effects on fruit length, diameter and weight, and at this concentration, values decreased which agrees with Shawer (2014) for cucumber with increasing $Cl^-$ concentrations increasing fruit length and diameter, but high $Cl^-$ (15.0 mM) concentration reduced fruit dimensions. High sodium chloride treatments negatively influenced fruit weight of tomatoes (Zahedifar et al., 2012).

There were significant linear relationship between fruit chemical characteristics and $Cl^-$ concentrations (Figure 2). The greatest dry matter content was in 3.0 mM $Cl^-$ treatments. Soluble solids contents increased up to 4.5 mM $Cl^-$ concentration and the greatest value was in this concentration. High dry matter, soluble solids and acidity contents were reported for salt-treated tomatoes (Leonardi et al., 2004; Helaly et al., 2017) and processing peppers (Turhan et al., 2014). Besides soluble solids content, increasing antioxidant capacities were reported with increasing salt concentrations (Peet et al., 2004). Effects of salinity on plants are mostly related to $Cl^-$ and $Na^+$ toxicity (Goyal et al., 2003; Zhu, 2003). The 6, 7.5 and 15.0 mM $Cl^-$ concentrations reduced dry matter and soluble solids content. Acid content increased with increasing $Cl^-$ concentrations and the greatest value was obtained from 7.5 and 15 mM $Cl^-$ treatments.

## CONCLUSIONS

Increasing growing media $Cl^-$ concentrations influenced growth parameters, yield, fruit characteristics, leaf $Cl^-$ content and water potentials of pepper plants. The threshold nutrient solution $Cl^-$ concentration was 3.0 mM for pepper plants, indicating $Cl^-$ concertation of nutrient solution should be kept at 3.0 mM and below. To determine the validity of the results studies under field conditions, for longer durations, with greater number of commercial species, are required.

### Statement of Conflict of Interest

Authors have declared no conflict of interest.

### Author's Contributions

The contribution of the authors is equal.

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